

sPHENIX Rate and Trigger Numbers...

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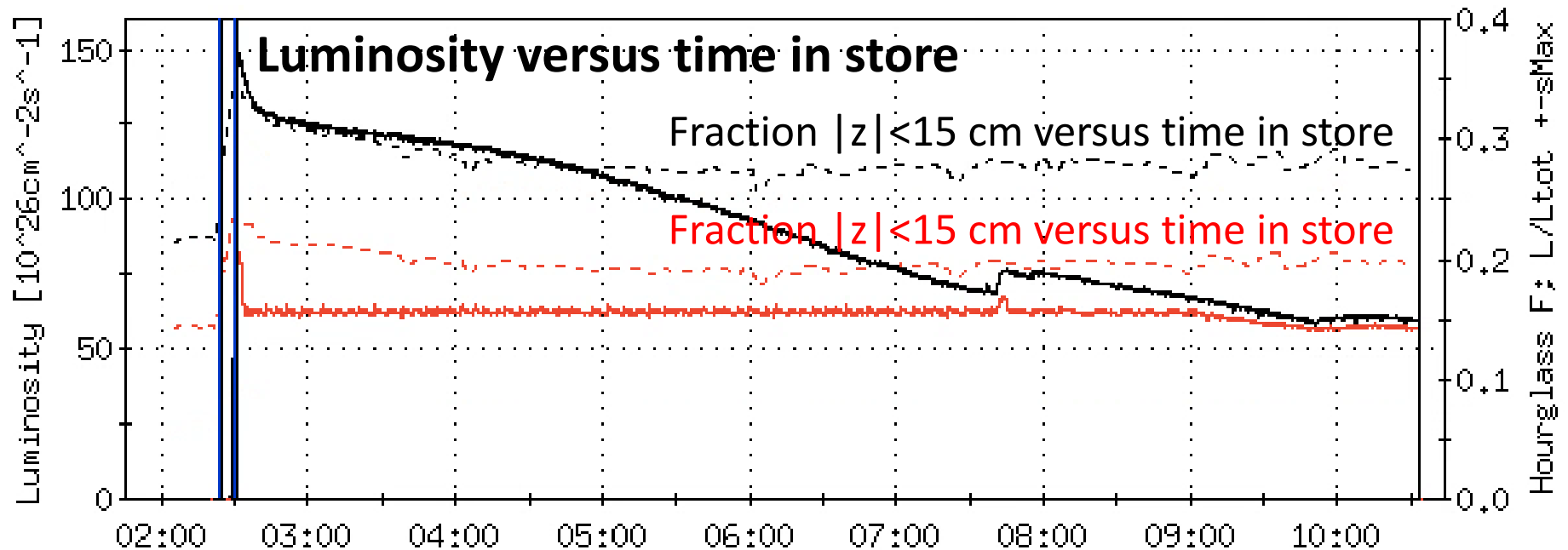
Last Updated 03/02/2017

Goal of these slides...

- 1) Update and Document Au+Au @ 200 GeV luminosity projections
- 2) Highlight implications for detector performance specifications
(need agreement)
- 3) Work towards a five-year run plan to discuss/show publicly

Email from Wolfram Fischer (01/28/2017).

“I have attached two plots, one from one of the best stores in p+p@200 GeV Run-15 (18925) and one from one of the best stores in Au+Au@200 GeV Run-16 (19645).”



Au+Au collision rate assuming 6.8 barn inelastic cross section...

	Total	Fraction $ z < 15$ cm	→	Rate
Peak at $150 \times 10^{26} \times 6.8\text{e-}24$	→ 102 kHz	35%	→	36 kHz
Within 15 minutes down to	→ 85 kHz	30%	→	26 kHz
Within 5 hours down to	→ 47 kHz	28%	→	13 kHz

RHIC Collider Projections (FY 2017 – FY 2023)

W. Fischer, M. Blaskiewicz, A. Fedotov, H. Huang, C. Liu, G. Marr, M. Minty, V. Ranjbar, D. Raparia

Last update: 6 January 2017

Updated 6 Jan. 2017 !

Table 3: Main upgrades planned for RHIC A+A and p↑+p↑ operation.

	A+A	p↑+p↑
For FY 2017	No beam operation planned	1 new 9 MHz RF cavity / ring Electron lenses tests at full energy
For FY 2018	56 MHz SRF upgrade (no HOM damper) 2 additional new 9 MHz RF cavities / ring	No beam operation planned
For FY 2019/20	LEReC (low energy cooling)	No beam operation planned
For FY 2023	In-situ beam pipe coating Landau cavity RF amplifier HOM damper for 56 MHz SRF	In-situ beam pipe coating

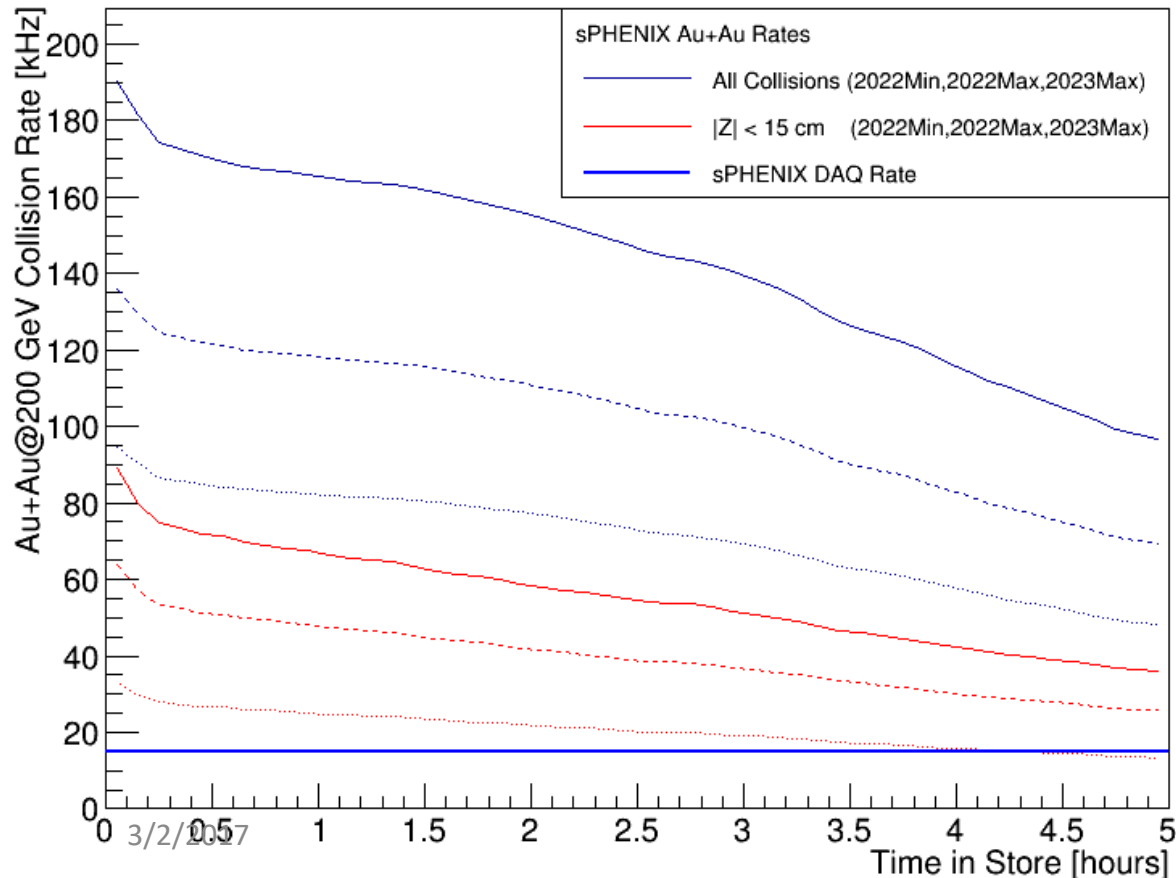
Table 4: Demonstrated and projected luminosities for 100 GeV/nucleon Au+Au runs.

Parameter	Unit	FY2010	2011	2014	2016	2022E	2023E
No of bunches	...	111	111	111	111	111	111
Ions/bunch, initial	10^9	1.1	1.3	1.6	2.0	2.3	2.5
Average beam current/ring	mA	121	147	176	224	253	275
Stored beam energy	MJ	0.39	0.47	0.56	0.71	0.81	0.88
Envelope function at IP β^*	m	0.75	0.75	0.70	0.70	0.65	0.60
Beam-beam parameter ξ /IP	10^{-3}	-1.5	-2.1	-2.5	-3.9	-4.4	-4.8
Initial luminosity	$10^{26} \text{ cm}^{-2} \text{ s}^{-1}$	40	50	80	155	211	270
Events per bunch-bunch crossing μ	...	0.10	0.13	0.21	0.40	0.54	0.69
Average/initial luminosity	%	50	60	62	56	60	65
Average store luminosity	$10^{26} \text{ cm}^{-2} \text{ s}^{-1}$	20	30	50	87	127	175
Time in store	%	53	59	68	65	62	62
Max. luminosity/week	μb^{-1}	650	1000	2200	3000	4750	6590
Min. luminosity/week	μb^{-1}					3000	3000

Consider 3 Au+Au @ 200 GeV running conditions...

- 1) Commissioning run at Run-16 best (refer to as 2022Emin) (22 weeks)
- 2) Physics Run at 2022E (2022Emax) maximum projections (22 weeks)
- 3) Physics Run at 2023E (2023Emax) maximum projections (22 weeks)

- Assume 62% RHIC update, 80% sPHENIX uptime...
- Pot. Sample = Potentially Sampled with selective trigger (TBC for each topic)



	MB Evts Record	$ z < 15$ Pot.Samp.	All z Pot. Samp.
1)	9.8e10	13.6e10	46.8e10
2)	9.8e10	26.0e10	67.2e10
3)	9.8e10	36.4e10	94.2e10

- 100 billion recorded per run.
- In super 2023Emax run, one could potentially sample 942 billion events (but 60% without tracking coverage).

How to approach a five-year run plan?

How many weeks to assume in each run?

Note that when we were constrained to two years, ALD said assuming 30 cryo weeks was OK. Should we back this down to 22 or 25 cryo weeks for 5 years?

How to estimate sPHENIX uptime (we used 80%), but that is probably high for a first run especially with the tracking?

Should we have 60% in the first commissioning run. Balancing effect – promising physics in Year-1 if running time is shorter and pushing importance of multi-year running.

How much detail do we want to include?

Realistic DAQ live time 90-95% (?), fraction of $|z| < 15$ cm obtained with Level-1 BBC type detector (what is the z-resolution, etc.)?

Note that for physics projections, we do not always want to assume the maximum (especially at the start). However, the detector, DAQ, trigger need to be designed with specifications to run in these optimistic maximum cases (or we cannot claim to aim for that physics).

Starting Point on 5-Year Run Plan Strawman...

1. Au+Au @ 200 GeV – commissioning + physics (22 running weeks ?).
Need high occupancy to fully understand the TPC, etc. Use 2022Emin projections...
2. p+p @ 200 GeV and p+Au @ 200 GeV
3. Au+Au @ 200 GeV – high luminosity running (22 weeks ?), 2022Emax projections...
4. p+p @ 200 GeV, maybe a new geometry (?)
5. Au+Au @ 200 GeV – super high luminosity (22 weeks ?), 2023Emax projections
 - assume adding physics from run 1, 3, 5
so for min.bias ~ 300 billion events
 - **sampled (see trigger slides next) with tracking 750 billion,
without tracking 2 trillion!**

Should we be just adding run 3 and 5 (i.e. not the commissioning run)?

What is the specification for the TPC on being able to handle charge distortions?

2022Emin – implies 100 kHz total

2022Emax – implies 140 kHz total

2023Emax – implies 200 kHz total

If we cannot handle the higher numbers, that is a major input issue on the five-year run plan and physics goals.

Do we need to wait 15 minutes to turn on the TPC? Other tracking detectors? Again specifications needed....

I have also confirmed with Wolfram that having a crossing angle lowers the collision rate, but does not help appreciably in any regard. Thus, we should not be referring to this publicly.

What might be triggerable and thus accessed beyond the 100 billion MB per year?

1. Direct photons should be straightforward > 10 GeV (see next slide).

Thus, in a 5-year plan, one could sample:

- * 2 trillion events for photon yields, photon-jet correlations
- * 750 billion events for photons with full charge tracking for opposite side fragmentation, medium response, etc.
- * Compare those to just 468 (136) billion in Year-1, which is already very optimistic if we are commissioning.

2. Jet triggering is more challenging in Au+Au, but may work for the highest energy jets (see next slide).
3. Upsilon triggering likely not to work in central Au+Au, but may be very valuable in more peripheral Au+Au.

Kurt & Dennis are making a new trigger emulator module. Direct photon trigger needs Au+Au rejection ($200 \text{ kHz} \rightarrow 1 \text{ kHz}$) of 200 or greater...

Easy to achieve and sample full luminosity. What is the priority to sample not only events with $|z| < 15 \text{ cm}$ with full tracking but also $|z| > 15 \text{ cm}$ for single photons and photon-jet or photon-energy distribution (no tracking).

Figures from the sPHENIX Proposal

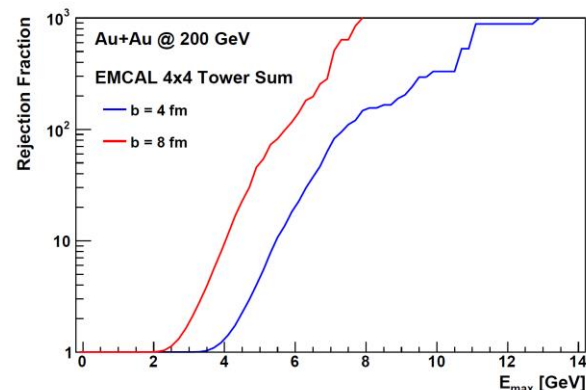


Figure 3.33: HIJING and GEANT4 calculated EMCal trigger patch 4×4 rejections for central and mid-central events ($b = 4$ and $b = 8 \text{ fm}$) as a function of threshold energy.

Jet patch trigger in Au+Au more challenging.

Needs much more detailed study with Emulator.

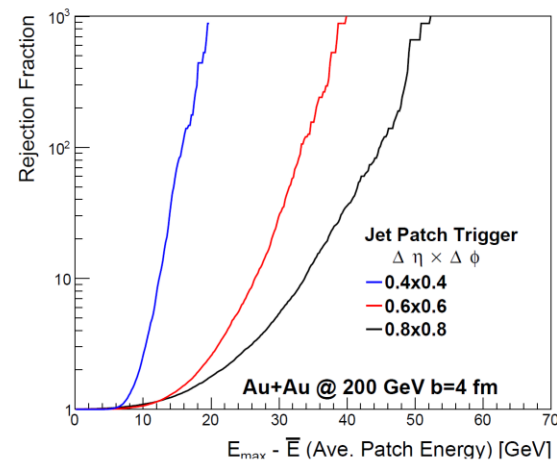
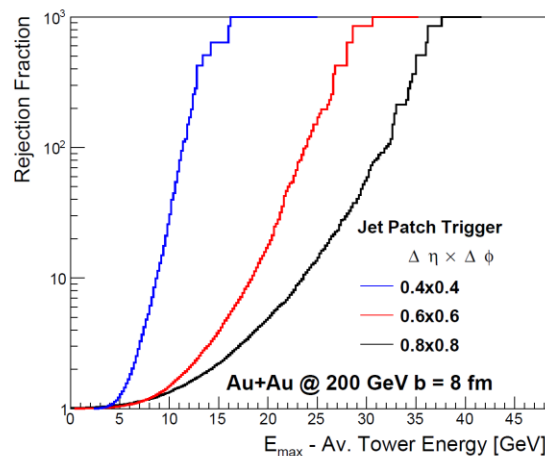


Figure 3.35: Full HIJING and GEANT4 calculated calorimeter (EMCal and HCal) trigger patch rejections for central and mid-central events ($b=4$ and $b=8 \text{ fm}$) as a function of threshold energy. The patch sizes considered are $\Delta\eta \times \Delta\phi = 0.4 \times 0.4$, 0.6×0.6 , and 0.8×0.8 .

Upsilon trigger via single electrons works well in p+p (as documented in proposal).

Very unlikely to work in central Au+Au, but perhaps in more peripheral events (which form CMS data might be where some interesting effects are happening).

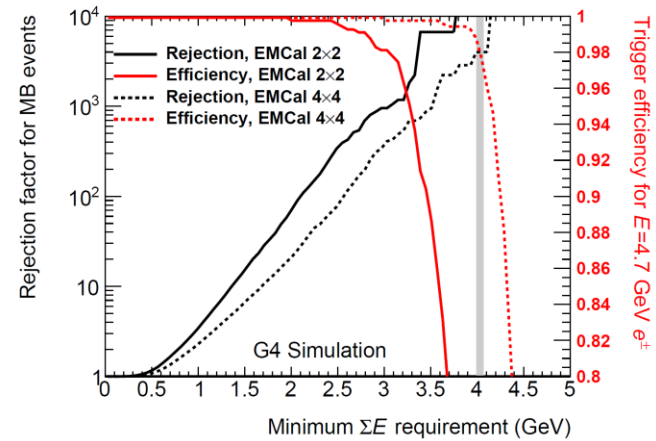
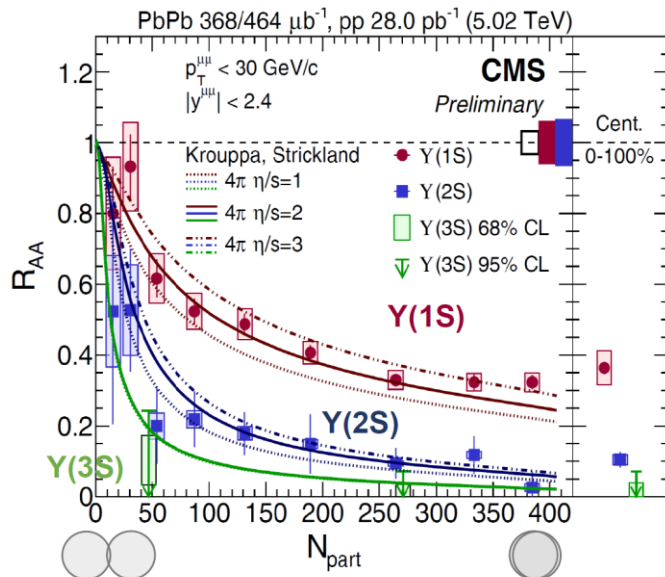


Figure 3.32: Rejection factor and efficiency for an electron trigger which requires some minimum amount of energy in a region of the electromagnetic calorimeter (ΣE). Results are shown for a full GEANT4 simulation of the detector response. The rejection factor for minimum bias $p+p$ events (black lines) and the efficiency for $E_{e\pm} = 4.7$ GeV electrons (red lines) are plotted as a function of the required energy ΣE . The solid and dashed lines show the results for trigger schemes in 2×2 and 4×4 EMCal windows.



Full emulator studies needed, including potential Invariant mass dilepton calculations.

- Highest precision measurement
- Upsilon sequential suppression at 5 TeV
- Still no sign of $Y(3S)$ with high statistics data

Reminder → sPHENIX Proposal Text (11/19/2014 version)

The effect of the completed stochastic cooling upgrade to the RHIC accelerator [144] has been incorporated into the RHIC beam projections [145]. Utilizing these numbers and accounting for accelerator and experiment uptime and the fraction of collisions within $|z| < 10$ cm, the nominal full acceptance range for the detector, the sPHENIX detector can record 100 billion Au+Au minimum bias collisions in a one-year 22 week run. In fact, with the latest luminosity projections, for the purely calorimetric jet and γ -jet observables with modest trigger requirements, one can sample 0.6 trillion Au+Au minimum bias collisions – see details in Section 3.8. Note that the PHENIX experiment has a nearly dead-timeless high-speed data acquisition and trigger system that has already sampled tens of billions of Au+Au minimum bias collisions, and maintaining this high rate performance with the additional sPHENIX components is an essential design feature.